installation costs. Infrastructure costs are primarily nodal and fiber applicable link costs—the cost of the ISAM equipment installation and the fiber link to that node. Allowing for a proportionate share of central office augmentation costs allocated to each node, the estimated cost per node approximates $83,000 of which $48,000 is for nodal equipment and $35,000 for the fiber optic cable link. This assumes an average fiber optic link of one mile from the central office to each node, and a weighted average cable installation cost of $35,000 per mile. The basis for the calculation of this weighted average cost is set forth below under the description of the cost structure for the Fiber-to-the-Premises alternative plan.

User acquisition costs for the FTTN Alternative Plan include the equipment and installation labor costs associated with the startup of service to a new user. Based upon an estimated four to eight hour installation time, and a typical user equipment cost of $150, the total new user equipment and installation cost may be estimated at about $600. Initially, service providers may absorb this cost to expedite the early growth of the network, but essentially this cost will have to be paid by each new user, either as an installation cost, or as a user cost to be absorbed as part of the monthly charges for the service. For these reasons, user equipment and installation costs were not considered in the comparative evaluation of alternative regional broadband communications plans.

4. Performance

   The Alcatel 7330 FTTN technology may be configured to provide a minimum target throughput of 25 megabits per second at each user location. The allocation of this bandwidth lies with the wireline service provider. Since television is the primary driving force behind the current FTTN network deployments, a sizable bandwidth allocation to video may be expected. A typical allocation might be 19 mbps for video, and 6 megabits per second for Internet data communications. As previously noted, a very small portion of the bandwidth is allocated to upload throughput.

Costs

As already noted, the FTTN Alternative Plan is envisioned to be deployed within an aggregate service area of 975 square miles—the planned design year 2035 urban service area within the region—or about 36 percent of the total area of the seven-county Region. This regional area is currently supported by 77 central offices each covering an approximate 12 square mile service area requiring 12 nodes per central office. At the previously estimated cost of $83,000 for each FTTN node, the cost attendant to the implementation of the FTTN alternative plans may be estimated at $77.7 million.

Cable Networks and the Fiber-to-the-Node (FTTN) Plan

Parallels exist between proposed ILEC-based FTTN networks and existing Hybrid Fiber-Coax (HFC) Networks employed by cable service providers. Both networks integrate combinations of fiber optic and copper wire linkages. Since cable networks now offer the same or equivalent services that are the primary target of the new FTTN network, it is reasonable to conclude that such cable networks could also offer fourth generation (4G) communications performance at throughput rates of 20 megabits per second and higher. Such upgrades to current HFC networks with download data rates as high as 100 Mbps have been reported. Charter Communications offers data rates as high as 30 megabits per second over its current HFC network. The structural topology of these HFC networks however, is also asymmetric and very downstream oriented in bandwidth allocation. Their geographic coverage, like FTTN, is also limited by the high costs of cable deployment.

Fiber-to-the-Premises (FTTP) Alternative Wireline Plan

The Fiber-to-the-Premises (FTTP) Alternative Plan is based upon the previously described Alcatel 7340 Fiber-to-the-Premises System which uses Passive Optical Network (PON) technology to reach new subscribers. A single fiber originating in a central office is split at a remote site using an optical splitter to connect up to 32 end users into the fiber network. Since there is no active electronic equipment between the central office and the user, the infrastructure deployment costs consist primarily of the cost of laying the fiber cable to the user's premises. The cost per user will depend on the household density in a given area. Since the costs of laying fiber cable per mile in various urban, suburban or rural settings are essentially fixed, the economic viability of FTTP depends on the population density of an area. Based on an average fiber optic cable deployment cost of $35,000 per mile, and an estimated 11 miles of cable required typically to serve one square mile of urban development area, the cost of installing the fiber optic cable would approximate $385,000 per square mile. The FTTP plan was assumed to serve the same area within the Region as the FTTN plan. This assumption was made to ensure comparability between the FTTN and FTTP alternative plans, although return on investment analyses would lead to smaller and different service areas for each plan.

The FTTP plan, like the FTTN plan, is central office oriented, so that deployment must consider the availability of central office locations as well as housing density. The long reach, however, of the Alcatel 7340 System—up to 12.4 miles—along with the ready availability of central offices to 400 household per square mile density areas should not seriously restrict the deployment of FTTP networks.

The FTTP plan has the following features:

1. Technology
   The Alcatel 7340 FTTP System is a second generation PON (passive optical network) platform that distributes voice, data and video transmissions through a passive (no electronic or electro-optic components) optical fiber network in which each fiber terminated at the central office (CO) can be split into 32 fiber lines at a remote Optical Splitter (OSP) for servicing up to 32 optical network terminals in homes or businesses. A PON network is selected in preference to an active optical network (AON) which provides for a direct fiber connection between each user and the CO. The AON has much greater potential capacity than a PON, but it also has a higher initial investment cost and higher operating and maintenance costs.

2. Range
   The Alcatel 7340 FTTP supports a range of up to 12.4 miles from the central office to the end user. At some intermediate distance, each co-originated fiber is split into 32 fibers, each one serving an individual.

3. Cost Structure
   The infrastructure costs of the FTTP Alternative Plan include the central office, fiber optic deployment and user premises installation costs. Infrastructure costs embrace only the first two of the cost elements since user premises installation costs occur only when a resident or business elects the service. User premises installation costs include the equipment and installation labor costs associated with the structure of service to a new user. These costs are absorbed by the user either in terms of an initial fee or as part of fees over the life of the service.

   The cost of laying fiber optic cable will vary widely with the type of area traversed—various urban, suburban, or rural settings—and with the design of the installation. For example, the City of Milwaukee installs its own fiber optic cables in ducts laid to line of grade properly related to the horizontal and vertical location of other utilities and to established street grades. The ducts typically consist of 4 inch diameter plastic tubing laid in groupings of one by two to four and four, and encased in a concrete slurry. Manholes are provided at junctions and at approximately 600 feet spacing between junctions. This represents the best municipal engineering practice, and should be followed for the installation of cable along arterial streets and in areas developed with high density urban uses, and therefore in which the street rights-of-way must accommodate a multiplicity of utility structures. The cable ducts are normally installed using trenching. In lower density urban, suburban and rural areas, the fiber optic cables are usually installed without benefit of duct work, utilizing cheaper plowing and directional boring techniques. The costs entailed may therefore range from a low of less than $20,000 per mile, to a high exceeding $250,000 per mile.

In the base year of the plan – 2000 –, there were a total of about 8,500 miles of public streets and highways within the planned urban service areas of the Region, of which 2,240 miles consisted of arterial streets and highways, and 6,260 miles consisted of collector and land access streets. As already noted, the collector and land access street network served a total of about 477 square miles of actual urban development within the 975 square miles of planned urban service area. Therefore, an average of 13 miles of collector and land access streets were required to serve one square mile of urban development together with an attendant two miles of peripheral arterial streets. Assuming that, typically, fiber optic cable would be installed only in about 67 percent of the collector and land access street mileage, about nine miles of cable would be required per square mile of urban development, plus an attendant two miles of cable in peripheral arterial streets. Assuming that duct installation would be required only for the fiber optic cable located in newly reconstructed arterial streets, and that 50 percent of the arterial streets in the urban service area will require reconstruction over the plan design period, duct installation would be required on average for about one mile of arterial street per square mile of development over the plan design period. Thus, for regional systems planning purposes, the cost of providing fiber optic cable service to the individual premises was estimated at $385,000 per square mile, with a weighted average cost for laying cable of about $35,000 per mile.

4. Performance
   The Alcatel 7340 offers high speed Internet access service up to 100 megabits per second. This data rate is far below the ultimate optical fiber capacity, but is constrained by the topology of the inactive PON network which has some of the same upload traffic limitations as hybrid fiber coaxial cable networks.

It is important to understand that a PON FTTP System is a shorter term solution that may in the future limit the full potential of fiber optics telecommunications in the coming years. An active optical network (AON) would have higher initial costs for both optical fiber and electro-optical equipment. It would also have higher operating costs in the form of equipment maintenance. It would, however, have essentially unlimited bandwidth and the ability to expand in service capability with future advances in electro-optical technology. This future potential would warrant consideration in the final step of an FTTP broadband wireline telecommunications plan.

Costs
The FTTP Alternative Plan is envisioned to be deployed within the same aggregate service area of 975 square miles or 36 percent of the seven-county Region as the FTTN plan, of which, as already noted, about 639 square miles would be devoted to actual urban development. Given the areal cost of about $385,000 per square mile, the infrastructure cost attendant to the implementation of the FTTP plan may be estimated at about $246 million.

ALTERNATIVE ADJUNCT PLANS

The primary alternative system plans herein presented serve only fixed and nomadic users. A complete telecommunications system for the Region would, therefore, require an adjunct network to serve mobile users. Although competing networks designed to serve mobile users currently exist within the Region, none is currently able to meet the objectives and standards set forth in Chapter III of this report. Therefore, each of the primary telecommunications system plans herein presented must be accompanied by an adjunct plan to provide mobile users with service meeting the objectives and standards set forth in Chapter III of this report.

Two technologies could be used to provide such adjunct service: WiMAX technology based on IEEE Standard 802.16e, or WiFi technology based on IEEE Standard 802.11a or g. The former technology employs licensed frequency bands primarily owned by existing wireless mobile service providers. The latter technology employs unlicensed frequency bands, and may be deployed as an extension of the primary community-based and the regional wireless system alternative plans. Deployment of the former technology is envisioned in Alternative Adjunct Plan A as herein presented, while deployment of the latter technology is envisioned in Alternative Adjunct

Plan B as herein presented. Alternative Adjunct Plan A is a potential supplement to all of the primary wireless or wireline plan alternatives; while Alternative Adjunct Plan B is a potential supplement only to the two primary fixed wireless plans—the community-based and the regional wireless system plans.

The technical limitations of mobile and nomadic user service rest primarily with the user's communications device. Both the laptop computer and the cell phone currently suffer from low performance radio receivers and low transmitter powers. Although transmitter power, particularly for unlicensed radio bands, is limited by the Federal Communications Commission, receiver technology is limited only by technical innovation. Such innovation may be expected to improve the wireless telecommunications performance of both cell phones and laptop computers. Each of the alternative adjunct broadband wireless telecommunications plans herein considered depend upon the continued advance of the state-of-the-art of wireless telecommunications technology.

Alternative Adjunct Plan A

Recognizing the dynamic evolving state of mobile wireless telecommunications technology, the formulation of Alternative Adjunct Plan A was based upon the assumption that the range of mobile wireless WiMAX antenna base stations will be extended from the current range of about 0.5 mile to at least 1.0 mile. It was further assumed that these assumptions will be met through the use of a combination of increased transmitter power and improved cell phone receiver sensitivity by equipment manufacturers.

Since it involves the use of licensed frequency bands, Alternative Adjunct Plan A must be deployed and operated by a wireless carrier with ownership of licensed frequency bands. Since Sprint-Nextel Communications is the only known national wireless service provider currently operating in Southeastern Wisconsin that has selected WiMAX technology for its next generation deployment, the antenna sites of this service provider within the Region as shown on Maps 12, 13, 19, 20, 26, 27, 33, 34, 40, 41, 46, 47, 53, and 54 of Chapter V of SEWRPC Planning Report Number 51, *A Wireless Antenna Siting and Related Infrastructure Plan for Southeastern Wisconsin,* September 2006, were used in the design of this adjunct plan. Extensive and accurate base station site data are available for Sprint and Nextel sites in Southeastern Wisconsin. The use of such base station sites in the plan design is not intended to imply that this alternative plan represents a recommended network layout for Sprint-Nextel Communications. Rather, use of the base station sites concerned allows for the preparation by the Commission of a meaningful and practical alternative plan that can be considered as a part of a final recommended comprehensive regional broadband telecommunications plan.

Alternative Adjunct Plan A was designed to offer the following features:

1. <u>Frequency Band</u>
   Alternative Adjunct Plan A would operate in the licensed 2.5 GHz frequency band with sub-bands selected based on Sprint-Nextel band assignments.

2. <u>Technology</u>
   System operation would be based on IEEE Standard 802.16e WiMAX technology.

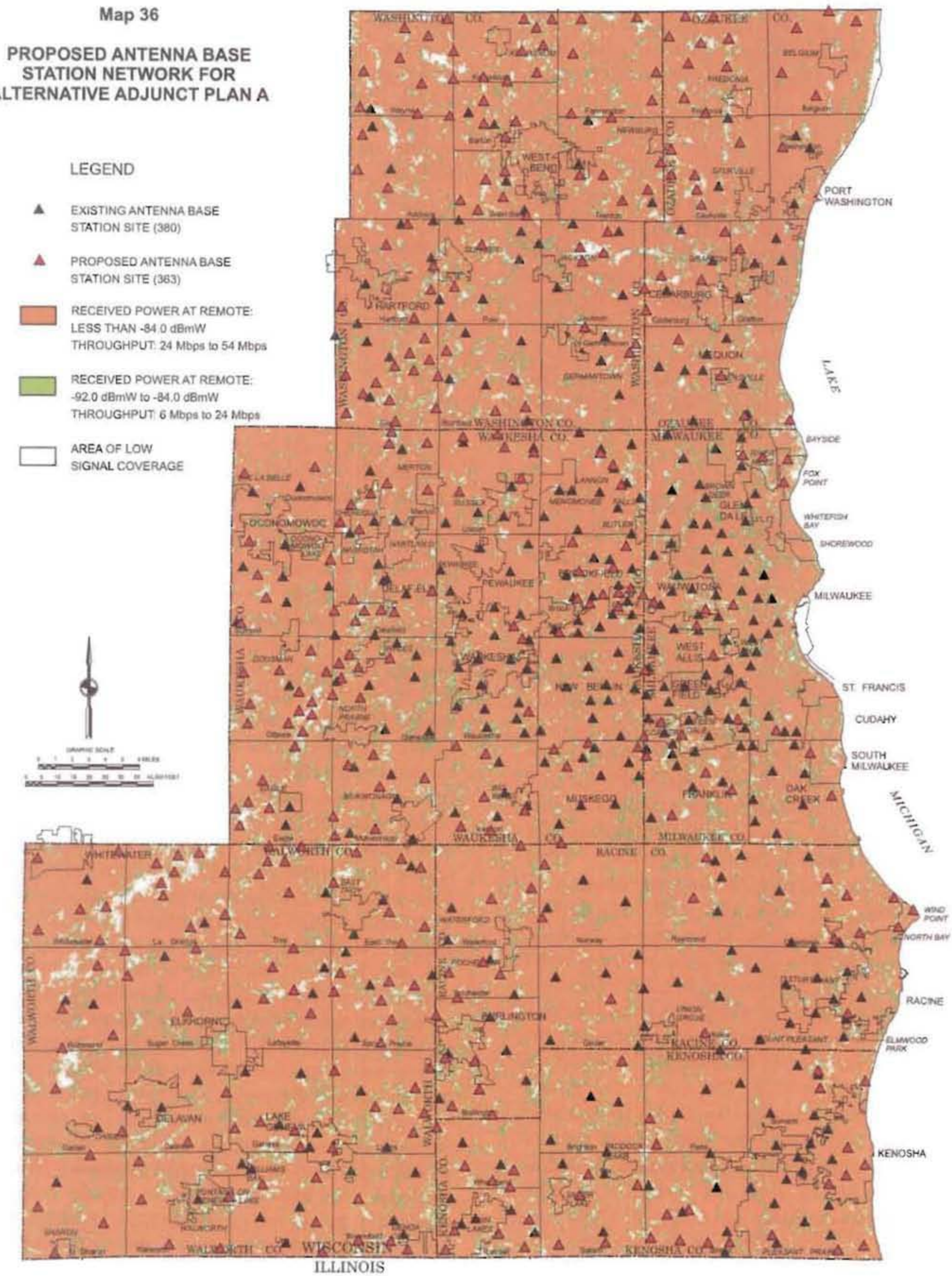
3. <u>Antenna Base Station Sites</u>
   The network infrastructure would be based on 380 existing antenna base station sites, and 363 new antenna sites necessary to provide universal service coverage within the Region.

4. <u>Antenna Site Layout</u>
   The antenna site layout for Alternative Adjunct Plan A shown on Map 36 was based upon radio wave propagation modeling. The modeling assumed that the antennas would be mounted at a height of about 100 feet above the base of the antenna base station masts. Variations in the antenna site density shown result from both the higher building "clutter" and higher traffic volumes expected for urbanized areas of the Region.

5. <u>Internet Gateway Connections</u>
   Consistent with the regional wireless system plans for fixed and nomadic users, the plan was based upon the provision of fiber optic gateway interconnections at each antenna base station site. Some of the current base stations have interconnections with a wire-

Map 36

PROPOSED ANTENNA BASE STATION NETWORK FOR ALTERNATIVE ADJUNCT PLAN A



Source: SEWRPC.

line network, but such interconnections may consist of either coaxial copper cable or fiber optic cable. The broadband nature of the proposed WiMAX based wireless network will require fiber optic cable interconnections.

6. Cost Structure
   The cost structure of the plan will be similar to that of the regional wireless plan for fixed and nomadic users except that costs will be increased to reflect the higher price WiMAX infrastructure equipment. The number of antenna base stations required for the plan reflects the conflicting effects of higher base station transmitter power versus low receiver sensitivity. Accordingly, the plan proposes the use of 743 antenna base stations to serve the Region.

7. Performance
   The network layout on Map 36 is designed to provide a minimum service level of six megabits per second throughput to mobile users within the Region.

Costs
WiMAX-based antenna base station costs may be expected to be similar to those shown in Table 18 for co-located backhaul base stations, except that WiMAX transceiver equipment would fully replace all WiFi equipment. Three WiMAX 802.16e transceiver modules would replace the WiFi-WiMAX combination given in Table 18 at an estimated cost of $15,000 per base station. This cost replaces the $5,800 of transceiver equipment cost listed in Table 18. Adding the needed fiber optic interconnections would entail an estimated cost of $2,500. Accordingly, the cost of a co-located WiMAX antenna base station site may be expected to total $25,000 and a new base station $37,500. With 743 base stations required, of which 363 would be new stations and 380 would be co-located stations, the estimated capital cost of the required base stations would total $23.1 million. The cost of the needed fiber optic cable connections would add an estimated $20,000 per site. Thus, the total capital cost of Alternative Adjunct Plan A is estimated to be $38 million. Operating costs are estimated at $5.6 million per month, based on a rate of $7,000 per month for a capacity of 100 megabits per second at each site and $500 for other expenses.

Alternative Adjunct Plan B –
Advanced WiFi and WiFiA
Alternative Adjunct Plan B can serve as an adjunct to either of the two proposed primary wireless service plans—the Community-Based Wireless Plan and the Regional Wireless Plan. As an adjunct to the Community-Based Wireless Plan, Plan B would provide mobile telecommunication service using IEEE Standard 802.11g technology. As a subsidiary to the Regional Wireless Plan, Plan B would provide service using IEEE Standard 802.11a technology. Alternative Adjunct Plan B would utilize the unlicensed spectrum, thus allowing WiFi network users an alternative compatible with their fixed and nomadic communications needs.

As already noted, wireless communications systems performance is limited in part by the sensitivity of the remote cell phone device. A typical cell phone antenna gain is only –2.0 dB. Such a low overall gain means that the cell phone antenna and any supporting amplifier actually attenuates rather than amplifies incoming voice or data signals. A gain of –2.0 dB means that the cell phone captures only 63 percent of an incoming signal. Such a low gain—coupled with the high signal-to-noise ratios required for data transmission severely limits the range of the broadband mobile communications antenna base stations concerned. Early high data rate WiMAX mobile telecommunications networks have antenna base station ranges of only about 800 meters—or approximately one-half mile. Such a system would require over 3,400 antenna sites to cover the seven-county Region. An expanded range of one mile may be expected to be provided by a later version of mobile WiMAX, and this would reduce the number of base station sites required to 856—a feasible maximum since there are currently 1,010 cellular/PCS wireless antenna sites within the Region. Increasing the range, and thereby decreasing the antenna base station density, depends primarily on the provision of either increased transmitter power or improved cell phone sensitivity or gain. In licensed frequency bands, transmitter power can be increased almost at the discretion of the service provider; given, however, technical limits on increased transmitter power due to potential interference in other cellular sectors of the network concerned. For the unlicensed frequency bands proposed to be used in Alternative Adjunct Plan B, transmitter power would be limited to about 4.0 watts. Such a limitation leaves improved receiver sensitivity as the only means for range improvement.

Another technology available for use with both WiFi and WiMAX to increase the range of base stations, is known as Multiple Input Multiple Output, or MIMO, technology. MIMO technology involves the use of multiple—from two to four—base station antennas and complex digital signal processing. Pre-certified WiFi versions of MIMO in the form of IEEE Standard 802.11n are now available in retail outlets. Early versions of mobile WiMAX will also incorporate MIMO. Experience to date, however, indicates range extensions have been modest, particularly if high data transmission rates are also required. Given the evolving nature of broadband 4G mobile wireless communications technology, Adjunct Plan B is based on the following assumptions in that the FCC limitations on transmitter power for the unlicensed 2.4 GHz and 5.8 GHz frequency bands will remain in force and that WiFi, and WiFiA mobile cellphone sensitivity enhancement—gain—may be expected to improve the current gain level of –2.0 dB to 10 dB. WiFi and WiFiA cellphone transmitter power may be expected to remain at the current level of 23 dB.

Based on the above assumptions, Alternative Adjunct Plan B has been specified to offer the following features:

1. Frequency Band
   Alternative Adjunct Plan B would utilize the 2.4 GHz frequency band in conjunction with the community-based primary wireless network plan; and the 5.8 GHz frequency band in conjunction with the regional based primary wireless network plan.

2. Technology
   The plan operation would be based on IEEE Standard 802.11g wireless technology in conjunction with the community-based primary wireless networks plan; and IEEE Standard 802.11a technology in conjunction with the regionally-based primary wireless network plan.

3. Antenna Access Points
   The adjuncts to the community-based wireless systems would use the same access points as the primary fixed and nomadic user service community wireless networks.

4. Example Community-Based Mobile WiFi Wireless Network
   As an example, a WiFi mobile wireless network plan was developed using the Cedarburg-Grafton fixed wireless infrastructure. This network employs the same access point locations as the fixed and nomadic user service network. It differs, however, in the sensitivity of the user device, a cell phone in this application. The network differs in the throughput performance levels which are indicated on Map 37 for a receiver sensitivity enhancement of 10 dB.

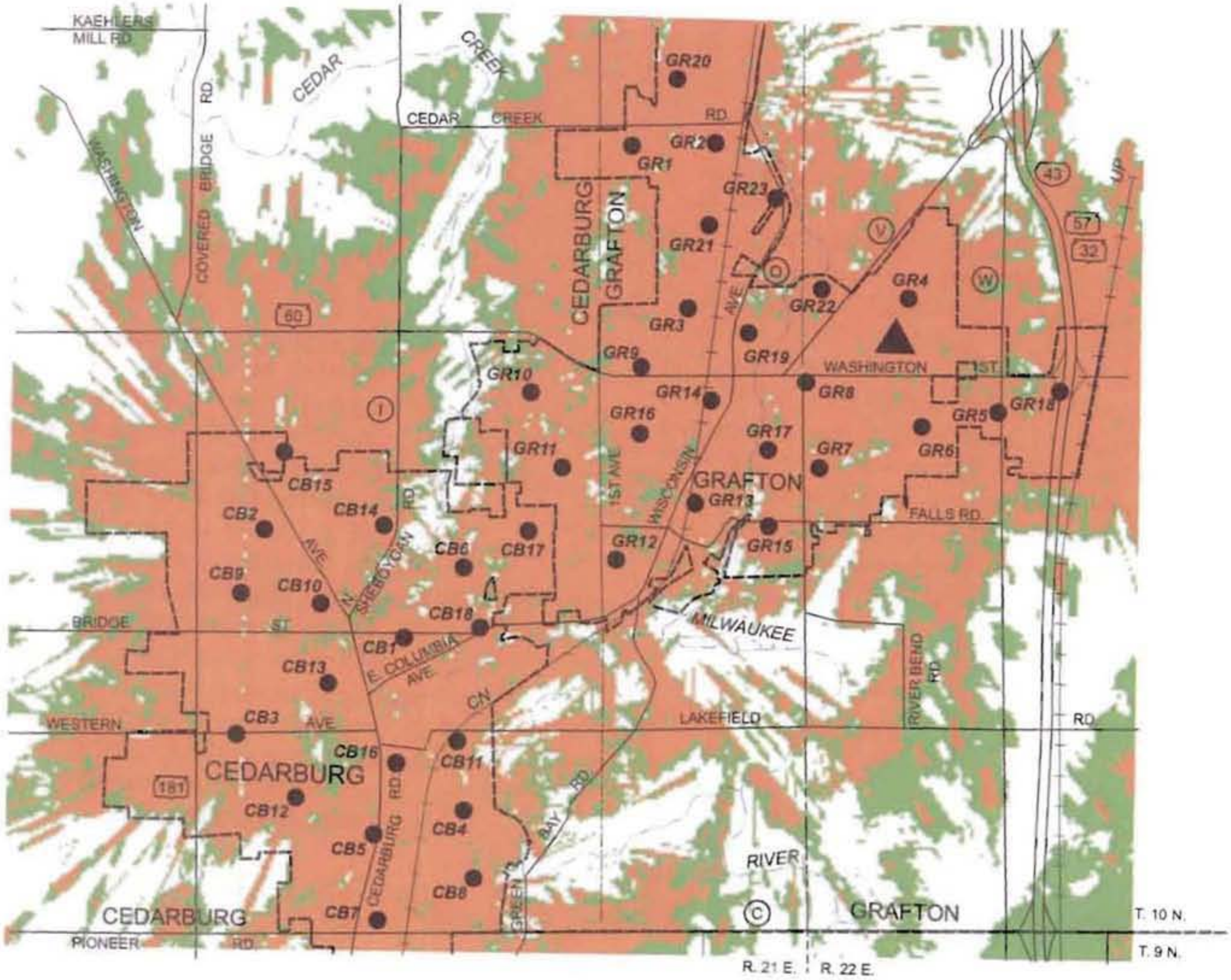
5. Regional Mobile WiFiA Wireless Network
   The Alternative Adjunct Plan B network would employ an infrastructure configuration taken from the primary service Regional Wireless Plan. It would differ in the areal performance levels possible as a function of receiver sensitivity. Based upon radio wave propagation modeling, Map 38 illustrates the mobile data rates possible for a cell phone antenna gain of 10 dB. Although data communications performance is emphasized as the primary criterion in all of the broadband mobile wireless plans, all of these networks would be able to provide for voice communication which has only modest bandwidth requirements.

6. Internet Gateway Connections
   The mobile wireless networks would be based on the same Internet gateway connections as the host fixed user networks. The community-based networks would generally have wireless backhaul to central gateway locations. The regional wireless network would have a fiber optic cable connection Internet gateway at each antenna base station site.

7. Cost Structure
   The cost structures of the community-based and regional network mobile wireless plans are identical to their host fixed wireless networks since they employ the same access points and base stations.

Map 37

SERVICE COVERAGE PROVIDED BY ALTERNATIVE ADJUNCT PLAN B COMMUNITY WiFi NETWORK



LEGEND

EXISTING BASE STATION TO BE USED FOR WIMAX APPLICATION

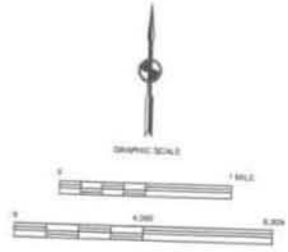
RECOMMENDED LOCATION OF WiFi ACCESS POINT

GR3 IDENTIFICATION NUMBER (SEE TABLE 17)

RECEIVED POWER AT REMOTE: -84dBmW TO -92dBmW, THROUGHPUT: 24 Mbps to 54Mbps

RECEIVED POWER AT REMOTE: GREATER THAN -92dBmW THROUGHPUT: 6 Mbps to 24 Mbps

AREA NOT WITHIN ACCEPTABLE COVERAGE



Source: SEWRPC.

Map 38

SERVICE COVERAGE PROVIDED BY ALTERNATIVE ADJUNCT PLAN B REGIONAL WIFIA NETWORK

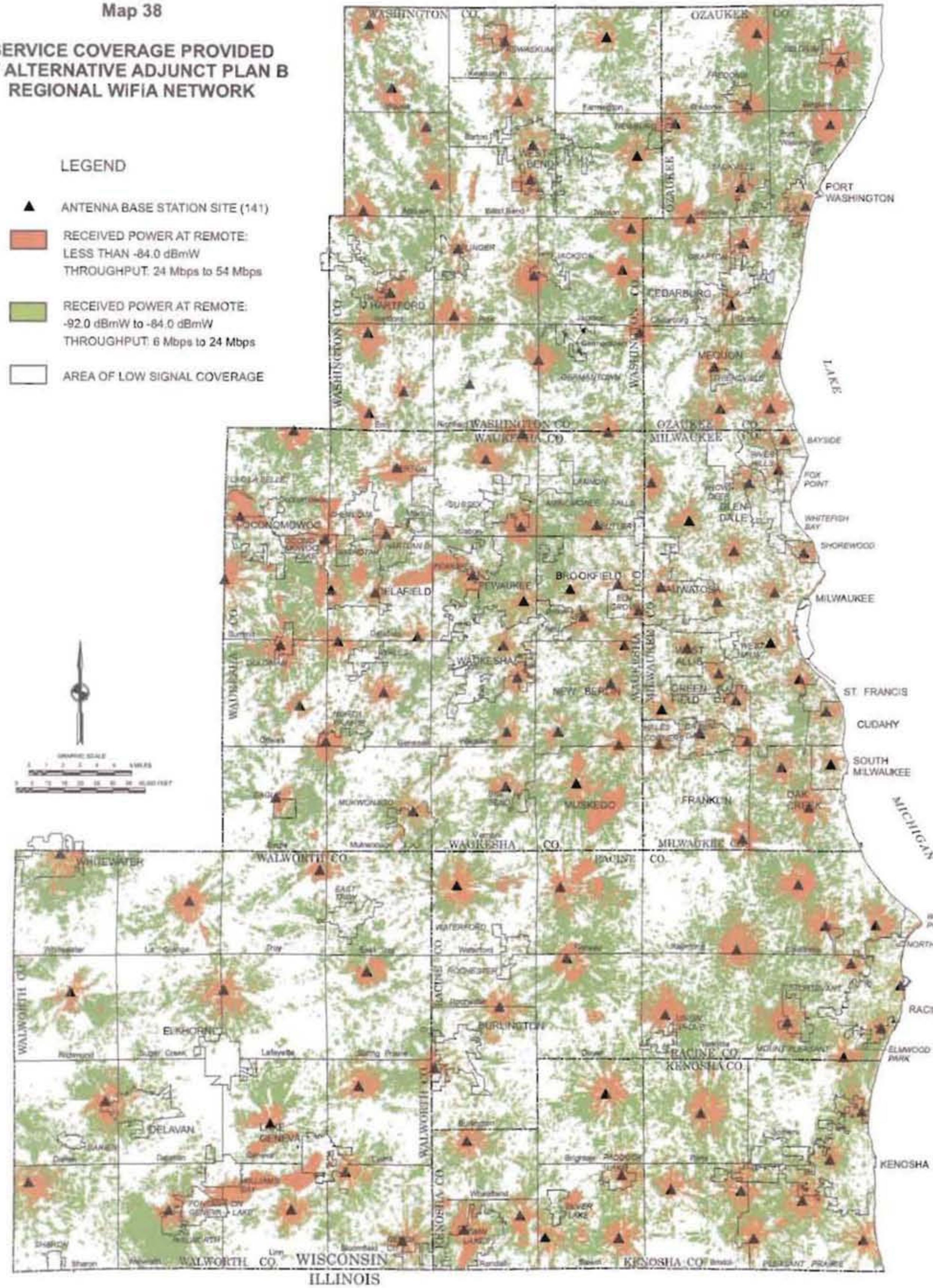
LEGEND

▲ ANTENNA BASE STATION SITE (141)

RECEIVED POWER AT REMOTE: LESS THAN -84.0 dBmW THROUGHPUT: 24 Mbps to 54 Mbps

RECEIVED POWER AT REMOTE: -92.0 dBmW to -84.0 dBmW THROUGHPUT: 6 Mbps to 24 Mbps

AREA OF LOW SIGNAL COVERAGE



Source: SEWRPC.

8. Performance
   As already noted, the performance levels of the two versions of Adjunct Plan B are shown in Maps 37 and 38. The prevailing data rate throughput is estimated to be in the 6 megabits per second range or better. It should be emphasized that laptop computer and WiFi cell phone active antenna gains were increased to the 10 dBi level from the current 5 dBi for laptop, and—2 dBi for WiFi cell phone equipment to achieve the indicated performance level. These remote devices constitute the "bottleneck" in extended range nomadic/mobile broadband communications. Remote device receiver sensitivity technology levels will need to be improved to achieve 4G performance objectives.

Alternative Adjunct Plan B Costs

As previously stated, there are no new infrastructure costs for either the community-based or the regionally-based mobile wireless networks. Both versions utilize fixed wireless host networks. Thus the capital cost of Alternative Adjunct Plan B when used in conjunction with a community-based fixed and nomadic user host network for the example Cedarburg-Grafton service area would approximate $353,000. The operating costs would approximate $4,600 per month.

The capital cost of Alternative Adjunct Plan B when used in conjunction with the regional wireless system host network would approximate $6.4 million. The operating costs would approximate $987,000 per month.

SUMMARY

The preparation of alternate regional broadband communications plans involved a seven step process:

1. Selecting a set of communications technologies for use in formulation of the plans;

2. Identifying infrastructure and user equipment requirements;

3. Developing performance data on the various technologies;

4. Developing cost data on the various technologies;

5. Preparing geographic network layouts of alternate plans;

6. Specifying the expected performance and costs of alternate plans; and

7. Evaluating each alternate plan in terms of the previously established objectives and standards.

The WiFi (IEEE 802.11g and 802.11a) and WiMAX (IEEE 802.16) standards were selected as the technologies for use in formulating the alternate wireless plans because they were the only technologies correctly specified to achieve the fourth generation performance targets. As IEEE standards technologies, they were also significantly lower in cost than competitive technologies. The Alcatel Fiber-to-the-Node (FTTN) and Fiber-to-the-Premises (FTTP) wireline technologies were selected for use in formulating the alternative wireline plans as typical of fiber communications technology today—Alcatel Lucent is the leading world provider of fiber communications systems. The current versions of these technologies, Alcatel 7330 and Alcatel 7340, may be expected to be electronically upgraded over the coming years, but the necessary basic fiber or fiber/copper infrastructures will remain essentially unchanged. The deployment costs—particularly of the FTTP technology—all more dependent on the construction costs of laying fiber than on the specific electronic equipment employed.

Having selected the basic technologies to be used in formulating the alternative plans, it was then necessary to specify equipment configurations for both the network infrastructure and the service users. The wireless equipment required special high gain antennas at both infrastructure access points and end users in order to achieve the performance standards previously established. Wireless plans were also based on a sectoral cellular topology to take advantage of the high gain active directional antennas. A conventional mesh network topology requires the employment of lower gain omni-directional antennas which do not have the gain performance necessary to achieve the 4G throughput standards. Performance estimates for a wireless network were based on manufacturers specifications,

Table 20

SUMMARY OF SALIENT CHARACTERISTICS OF ALTERNATIVE REGIONAL TELECOMMUNICATIONS PLANS

Plan	Universal Geographic Coverage	Performance	Infrastructure Cost	Redundancy	Public Safety	Most Demanding Application
Community-Based Wireless Plan	Geographic coverage depends on a community-by-community plan implementation	Meets the throughput standard but may have less speed improvement potential than fiber-based systems	Plan is much lower in cost than fiber-based systems $20.3 million	Built-in redundancy is possible using peer-to-peer communications feature to be field tested as part of the regional wireless plan	Joint 4.9 GHz frequency operation for public safety communications is possible as an added feature in a community network	Plan is not designed for broadcast video services but is well suited to video conferencing
Regional Wireless Plan	Plan specifies coverage for the entire Region, but implementation depends on a county-by-county deployment	Meets the throughput standard but may have less speed improvement potential than fiber-based systems	Plan is the lowest in infrastructure cost by a wide margin $6.4 million	Plan will have inherent redundancy for both alternative transmission paths and for failure of infrastructure base stations	Plan has specific separate network for public safety	Plan is not designed for broadcast video services but is well suited to video conferencing
Fiber-to-the-Node (FTTN) Wireline Plan	Plan will cover only 35 percent of the geographic areas of the Region	Plan will meet throughput standards in the downstream but not the upstream direction	For a third of the geographic coverage, plan is more than 10 times the cost of the Regional Wireless Plan $77.7 million	Plan has no explicit redundant transmission paths	Plan does not specifically provide for public safety communications except for priorities in times of public emergency	Plan emphasizes the video broadcast application. Slow upstream throughput is not compatible with video conferencing
Fiber-to-the-Premises (FTTP) Wireline Plan	Plan, like the FTTN plan, covers only 35 percent of the Region	Plan will have the greatest throughput potential of any plan	It is the most costly of all of the plans $246.0 million	Plan has no explicit redundant transmission paths	Plan does not specifically provide for public safety communications except for priorities in times of public emergency	Plan is well suited to both broadcast video and video conferencing
WiMAX Mobile Wireless Plan A	Economic considerations will limit coverage in low density rural area	Plan provides for 4G throughput performance	The cost far exceeds that of the WiFi mobile wireless plan $38.0 million	There is no provision for network redundancy	There are no specific public safety features in this plan	Videoconferencing is supported in this plan
WiFi Mobile Wireless Plan B	Operating with both the regional and community-based wireless networks, this plan provides for full regional coverage	Plan provides for 4G throughput performance	Infrastructure costs are minimal and relate to augmentations of the other two wireless plans $1.0 million	Plan calls for redundancy using peer-to-peer transmission paths	Plan allows for integration with 4.9 GHz public safety wireless network	Video conferencing is supported in this plan

Source: SEWRPC.

radio propagation modeling and extensive field testing with the specified equipment. Wireless cost data were collected from manufacturer price schedules. The estimated geographic coverage of wireless network plans was based primarily on radio propagation modeling verified by field testing.

Fiber-to-the-node (FTTN) and fiber-to-the-premises (FTTP) equipment requirements, performance data and cost data were all obtained from Alcatel specifications and pricing schedules as confirmed by cost data publicly available from either corporate financial reporting or the FCC.

A summary of the characteristics of the alternative broadband wireless and wireline communications plans in terms of plan objectives and standards are set forth in Table 20. The plan characteristics shown in the table will be used to evaluate alternate plans and select a final plan in the next chapter.

Chapter VIII

ALTERNATIVE PLAN COMPARISON AND EVALUATION AND SELECTION OF A RECOMMENDED PLAN

INTRODUCTION

The previous chapter of this report described a set of alternative wireless or wireline broadband telecommunications plans that alone, or in combination, were candidates for a recommended comprehensive, regional telecommunications plan for Southeastern Wisconsin. This chapter presents the findings of a comparative evaluation of these alternative plans; and based upon these findings sets forth a recommended plan. The plan selection process looks back to Chapter III of this report which defines the objectives, principles and standards that are intended to serve as the basis for the comparative evaluation of the various alternative and adjunct plans considered, and for selecting one of these alternative plans, or combination of these plans, as the preferred plan for future broadband telecommunications within the Region.

METHOD OF EVALUATION

In the preparation of long range public works facilities plans, the Commission usually uses the benefit-cost analysis method for the comparative evaluation of alternative plans. Although this method may be theoretically applicable to the shorter range alternative telecommunication system plans presented in this report, the method loses much of its effectiveness in such application because of the following limitations:

1. It is impractical to assign a monetary value to the many intangible benefits and costs attendant to telecommunication system development within the Region, and it is extremely difficult to assign monetary values to even the direct benefits and costs associated with such development.

2. Because of the relatively greater uncertainty associated with implementation of a regional telecommunications plan, there can be no assurance that the potential benefits will ever be realized, even though some of the costs associated with the development of a given system may, nevertheless, be incurred.

It was determined that the alternative telecommunication system plans considered would be compared by scaling each plan against each development objective set forth in Chapter III of this report, utilizing the standards supporting each objective and the results evaluated by the Regional Telecommunications Advisory Committee. In addition, the comparative evaluation was supplemented by the application of a method which seeks to assign a value to each alternative plan.

The method chosen, overcomes, to a considerable extent, the difficulties inherent in the application of benefit-cost analysis to telecommunication system planning. The method is an adaptation of the rank-based expected value method used for corporate and military decision making.[1] This method avoids the difficulties associated with the assignment of monetary values to potential benefits and costs associated with the alternative plans by limiting the plan evaluation problem to one of rank ordering each alternative under each of the stated development objectives. It is usually easier to rank order the perceived effectiveness of a given plan in achieving a given development objective than it is to attempt to assign monetary values to the benefits accruing to the attainment of the objective.

The difficult problems associated with uncertainty of plan implementation are also ranked in the chosen method of plan evaluation through the medium of probability estimation. Some alternative plans, while theoretically highly desirable, may have a low probability of implementation; and, in the application of the method, such plans are assigned a lower value for probability of implementation. Other plans, while theoretically less desirable on the basis of the ability to attain stated objectives, may have higher actual value because of a greater likelihood of implementation.

In plan evaluation, then, the application of the rank-based expected value method involves the following sequence of activities.

1. All specific development objectives, n in number, are ranked in order of importance to the agreed upon development objectives and assigned "weight" of n, n minus 1, n minus 2, and so on to n minus one (n-1) in descending rank order.

2. The alternative plans, m in number, are ranked under each of the specific development objectives and assigned a "score" of m, m minus 1, m minus 2, and so on to m minus one (m-1) in descending rank order.

3. A probability, p, of plan implementation is assigned to each of the plans being ranked.

4. The value, V, of each alternative plan is then determined by summing the products of n times m times p for each of the specific development objectives, or:
$V = p \sum (n_1 m_1 + n_2 m_2 + \ldots + n_n m_n)$

In Chapter III of this report, specific telecommunication system development objectives were expanded into sets of supporting standards which could be used to evaluate the ability of an alternative plan to achieve a given specific development objective. Any ranking of an alternative plan for a given specific development objective must, therefore, be consistent with the ability of the plan to achieve the supporting standards set forth for that objective. To achieve this consistency, it is necessary to compute a value for each of the alternative plans according to the supporting standards set forth for each development objective before arriving at an overall value for each plan in relation to the development objectives. This subsidiary evaluation utilizes a series of matrices in which the development standards replace the development objectives in the matrix table, and in which it is usually not necessary to assign a probability estimate for the standard evaluation.

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[1] *C. H. Igor Ansoff,* Corporate Strategy, *McGraw-Hill, New York, N.Y., 1965; K. J. Schlager, "The Community-The Rank-Based Expected Value Method of Plan Evaluation,"* Highway Research Board, *1968; Z. Hu, et al., "Fuzzy Expected Value model for Transmission Planning with Hybrid Intelligent Algorithm,"* Computers and Advanced Technology in Education Conference, *October 8-10, 2007, Beijing, China; Yian-Kui Liu and Baoding Liu,* Information Sciences, *Volume 155, Issues 1-2, 1 October 2003, Pages 89-102.*

Ranking the Objectives/Standards
From the eight sets of objectives and standards presented in Chapter III, six were selected to serve as a basis for the comparative evaluation of the alternative plans.

1. Performance

2. Universal geographic coverage

3. Infrastructure cost

4. Redundancy

5. Public safety

6. Most demanding application – video and multimedia

The other two objectives: antenna base site minimization, and antenna aesthetics and safety were not used in the evaluation since these apply only to wireless telecommunications systems, and so can not serve as a basis for comparing wireline and wireless systems.

The above objectives were also ranked in a perceived order of priority—or importance—beginning with the highest in priority listed first. Performance was ranked first since it represents the very definition of broadband telecommunications. Performance is also strongly related to the economic development goal of the telecommunications planning program. Universal geographic coverage was ranked second since such coverage is not likely to occur within Southeastern Wisconsin through the operation of market forces alone and without strong governmental incentives and encouragement. Infrastructure cost also rank high since this cost is an important determinant of the economic viability of an alternative plan. Redundancy is an important feature of any telecommunication system because of the need for system reliability in a wide range of public and private applications. Public safety was designated an objective in its own right because maintenance of public safety and effective response to natural and man-made disasters represent two of the most important uses of modern telecommunications. Finally, the ability to meet the most demanding use of the telecommunications bandwidth—video telecommunications—was considered important to certain business and governmental functions as well as to the entertainment function of telecommunications systems.

EVALUATION BASED UPON STANDARDS

Prior to the application of the rank-based expected value method (RBEV) to aid in the selection of a regional comprehensive broadband telecommunications plan, each of the four alternative and two adjunct plans were evaluated and ranked on the basis of the ability to meet the supporting standards under each of the six objectives. Such an evaluation and ranking then provided the basis for final plan selection.

Performance Objective
The performance objective, as defined in Chapter III, embraces not only throughput—transmission rate—but also network reliability and quality of voice communications. Ranking the alternate plans for this objective can be readily accomplished based upon the nature of the four alternate plan technologies. An all fiber network, as represented by the FTTP plan, would clearly be first in rank in this respect. If the active (AON) rather than the passive (PON) optical network had been the selected technology, there would be little or no limit on ultimate network performance. PON technology does have some limitations based on network topology, but even with these restrictions, the FTTP has the highest ultimate performance potential. While the electronic equipment for wireline network may be expected to continue to evolve and improve, the fiber infrastructure will impose little or no performance limitations for many years to come.

The remaining plan alternatives, FTTN wireline and the two broadband wireless plans all promise to achieve 4G performance levels. The wireless plans, however, while competing favorably on throughput performance short-term and long-term, will probably never achieve the "five nines—99.999 percent—reliability of wireline networks.

Based upon the foregoing considerations, the four alternative plans were ranked for performance as follows:

1. Fiber-to-the Premises (FTTP) Wireline Plan

2. Fiber-to-the Node (FTTN) Wireline Plan

3. Regional Wireless Plan

4. Community-Based Wireless Plan

Universal Geographic Coverage Objective

The universal geographic coverage objective, ranked second in importance among the six plan objectives, is one well suited to plan comparison and evaluation. Only the two wireless alternative plans make such widespread geographic coverage a feasible object-tive. The Fiber-to-the-Node (FTTN) and Fiber-to-the-Premises (FTTP) wireless alternative plans would serve about 36 percent of the total area of the Region and, therefore, cannot achieve high rank for geographic coverage. Those alternative plans may, however, be expected to serve about 92 percent of the anticipated year 2035 resident population of the Region; about 93 percent of the land anticipated to be devoted to commercial use within the Region; and about 90 percent of the land anticipated to be devoted to industrial use within the Region in that year. The community-based wireless plan has the potential for full geographic coverage of the Region, but such full coverage would depend on the deployment of broadband wireless networks in each of the Region's 147 cities, villages and towns, or in a somewhat smaller number of cooperative municipal service areas. Such a universal adoption and deployment of broadband wireless networks is considered highly unlikely. Even if each muni-cipality were to desire the installation of a community-based wireless network, there is no assurance, especially in low density rural areas, that private, or public, capital funds would be available to support the needed infrastructure deployment. This potential lack of capital funding should not, however, be interpreted as indicating that there would be little demand for high-speed broadband telecommunications services in low density rural areas of the Region: experience has indicated the opposite to be true. Only the regional wireless plan alternative has both the economic rationale and governmental support structure required for the attainment in a timely fashion of region-wide geographic coverage. The economic rationale is provided by a joint public safety-commercial antenna site infrastructure. The governmental support, however, would have to come from the counties. While the regional wireless plan is truly region-wide in scope, the required joint public safety-commercial antenna site network could be accomplished on a county-by-county basis.

Based upon the foregoing considerations, the four alternative plans were ranked for geographic coverage as follows:

1. Regional Wireless Plan

2. Community-Based Wireless Plan

3. Fiber-to-the-Node (FTTN) Wireline Plan

4. Fiber-to-the Premises (FTTP) Wireline Plan

Infrastructure Cost Objective

Two methods were used to determine the infrastructure costs of the alternative plans. The first set of infrastructure costs was limited to the actual capital costs of the infrastructure equipment with no provision for operating costs. The second method included the capital costs of the first method plus the present value of that portion of the operating costs representing capital substitution costs, i.e. the incrementally higher Internet access costs resulting from the purchase of Internet access locally at each antenna site rather than regionally based on a optic fiber cable backhaul network allowing for lower Internet access costs.

Based on the first method, the following infra-structure costs were estimated:

1. Community-based Wireless Plan – $20.3 million

2. Regional Wireless Plan – $6.4 million

3. Fiber-to-the-Node Wireline Plan – $77.7 million

4. Fiber-to-the Premises Wireline Plan – $246.0 million

Ranking of the alternative plans on the infrastructure cost minimization objective was also accomplished on the basis of the infrastructure costs plus the present value of any higher operating costs resulting from the avoidance of increased fiber infrastructure costs that would result in lower operating rates. The basic direct Internet access rate for the 141 base station sites of the Regional Wireless Plan and the 54 backhaul stations of the Community Wireless Plan is $70 per megabit per second per month. If additional fiber optic infrastructure were installed allowing for high volume Internet connections in the 5 gigabit per second range at only three connections, the Internet access rate would drop to $45 per megabit per second per month. The $25 per month difference in the two rates was then capitalized based on the present value of the payments over a ten year period at 5 percent interest rate. The modified infrastructure costs using the second method change only for the two wireless plans. The wireline plans are assumed to have no substituted capital costs in their operating costs. Under the second method, the modified infrastructure costs were estimated as follows:

1. Community-based Wireless Plan – $38.6 million
2. Regional Wireless Plan – $39.1 million
3. Fiber-to-the-Node Wireline Plan – $77.7 million
4. Fiber-to-the-Premises Wireline Plan – $246.0 million

The above infrastructure cost estimates assume that the full cost of the regional wireless plan will be borne by the private service provider. In the actual implementation, the public safety wireless communications network will utilize the same base station infrastructure and share the deployment costs. The effect of such cost sharing considerations will be considered later in the final plan selection.

All cost estimates here are based on the detailed cost breakdowns developed in Chapter VII which included wireless infrastructure costs in Table 18 and wireless operating costs in Table 19 Wireline cost estimation methodology is covered in the text for each plan alternative.

Redundancy Objective

The inclusion of redundancy as a separate objective was based, at least in part, on the almost universal failure of telecommunication networks, both public and private, in recent national natural and terrorist-inspired post disaster environments. Wireline and wireless networks failed to a large extent to operate after both the September 11, 2001, terrorist attack on the World Trade Center in New York and the Gulf hurricane of 2005 that destroyed much of the New Orleans area. Wireline as well as wireless telecommunications networks are critically dependent on major infrastructure elements such as central offices and antenna base sites. A variety of disaster-induced events such as explosion, grid power loss, or flooding as well as terrorist inspired sabotage, can severely damage telecommunication infrastructure. Emergency-related network traffic congestion can also disable a network even when the infrastructure remains intact. Network redundancy can also play an important role in normal network operation where high network reliability is required to maintain government, commercial and social communications—especially public health and safety related communications. Wireless networks in particular have experienced reliabilities far below the 99.9 percent standard due to a lack of network redundancy.

As already noted under the performance objective, wireline networks have demonstrated very high reliability in network operations. Such wireline networks, however, do not have known elements of network redundancy. Both the FTTN and FTTP networks are critically dependent on the operation of central offices. A disruption of a single central office operation may disconnect the entire service area of that office. In like manner, loss of a single antenna base station site can disrupt wireless communications over a wide service area. Protection against such communication disruptions requires redundancy in the network. Redundancy was defined in Chapter III as the "average number of alternative transmission paths between users in a network". Accordingly, network redundancy is created by providing alternative transmission paths through the networks. Traditional cellular wireless networks do not typically provide redundancy in the form of alternative transmission paths through the networks. Users communicate through the antenna base stations assigned for a particular time and location. Operational failure of the base station concerned will terminate all communications in the station service area. Established alternative paths are generally not available.

The most redundant communications network topology is the mesh network design. In a mesh network, users with omnidirectional antennas may connect with alternative access points. Once connected, alternative transmission paths through the network provide strong redundancy as long as sufficient access points are available for such redundant transmission paths. Power outages and other emergency situations, however, can still drastically reduce the number of such alternative transmission paths. Comprehensive wireless network redundancy requires alternative transmission paths that are independent of the basic infrastructure. Such redundant independence is possible only in ad hoc, peer-to-peer mesh networks that employ the users themselves as backup transmission point nodes. Such an ad hoc mesh network differs from current mesh networks in two primary ways: (1) the ad hoc, peer-to-peer network serves only as an emergency supplement to the basic cellular network; and (2) the mesh network nodes are end users, serving as nodes not separate network elements. Both the community-based and regional wireless plans are envisioned as incorporating this backup ad hoc, peer-to-peer network feature to provide high levels of redundant network operation.

Redundant features of the FTTN and FTTP wireline networks, if any, are unknown at the present time. The basic structure of these networks does not lend itself to redundant transmission paths. Both are critically dependent on central offices for basic operation. Alternate paths to remote nodes from the host, or from another central office, are not known to be provided. Disabling a node in an FTTN network will terminate communications in its square mile service area. Failure of a splitter node in a FTTP network will terminate communications in its service area. In the absence of additional information, redundancy in the FTTN and FTTP wireline networks must be assumed to be low or nonexistent. The redundancy of an FTTP network must be rated better than an FTTN network only because a fiber splitter is a passive component, while a FTTN node operates with active electronic equipment. Based on the forgoing considerations, network redundancy for the alternative plans was ranked as follows:

1. Regional wireless plan
2. Community-based wireless plan
3. Fiber-to-the-premises (FTTP) wireline plan
4. Fiber-to-the-node (FTTN) wireline plan

Public Safety Objective

The public safety objective relates to the response of the telecommunications system in supporting public safety objectives both in normal operations and in public safety emergencies. Because the Regional Wireless Plan would be jointly designed with the public safety communications network, it would directly support public safety communications in the Region. Community-based wireless networks may also choose to integrate network access points, or antenna base stations, into a shared public-commercial framework in which infrastructure development costs are shared. Such cost sharing directly enhances public safety by leveraging the public safety communications investment for enhanced public safety communications performance.

Wireline networks, since they do not support mobile, or nomadic users, are less directly involved with public safety communications. Wireline networks, however, are routinely used for public safety communications between fixed locations, and can serve the public safety objective by granting priority to public safety traffic particularly in times of public emergency. The FTTN broadband wireline network would be particularly useful to public safety because of its wider availability throughout the Region. Based on the foregoing considerations, the alternative plans were ranked as follows:

1. Regional wireless plan
2. Community-based wireless plan
3. Fiber-to-the-node (FTTN) wireline plan
4. Fiber-to-the premises (FTTP) wireline plan

Most Demanding Application Objective

Video, in both its broadcast and videoconferencing forms, is the most demanding broadband communications application. Bandwidth requirements for video can range from 256 kilobits per second to 200 megabits per second depending on application and desired quality. Broadcast television, even in its least demanding form, requires at least five megabits per second. The FTTN and FTTP plans, as presently being deployed by telephone carriers, such as AT&T and Verizon, are primarily aimed at the broadcast television market. As presently constituted, they are asymmetric and so do not support high quality videoconferencing. Videoconferencing, however, has not yet developed as a major application, and so generates minor traffic in comparison to broadcast television. For this reason, the plans were ranked primarily on their downstream throughput performance as follows:

1. Fiber-to-the premises (FTTP) wireline plan
2. Fiber-to-the-node (FTTN) wireline plan

Table 21

COMMUNITY-BASED WIRELESS PLAN RANKINGS AND RELATED SCORES

Item	Performance	Universal Geographic Coverage	Infrastructure Cost	Redundancy	Public Safety	Most Demanding Application
Rank	4	2	1	2	2	3
Score	1	3	4	3	3	2
Weight	6	5	4	3	2	1
Value	6	15	16	9	6	2

Note: Summation of the above value provides a total valuation score of 54.

Source: SEWRPC.

Table 22

REGIONAL WIRELESS PLAN RANKINGS AND RELATED SCORES

Item	Performance	Universal Geographic Coverage	Infrastructure Cost	Redundancy	Public Safety	Most Demanding Application
Rank	2	3	3	3	3	2
Score	3	2	2	2	2	3
Weight	6	5	4	3	2	1
Value	18	10	8	6	4	3

Note: Summation of the above value provides a total valuation score of 65.

Source: SEWRPC.

3. Community-based wireless plan

4. Regional wireless plan

Rank-Based Expected Value Plan Evaluation

Plan evaluation using the rank-based expected value method involves the combination of rank value calculations and an estimate of the probability of implementation. Beginning with the community-based wireless plan, each plan was scored based on these rank valuations and implementation probability estimates.

Community-Based Wireless Plan

The community-based wireless plan received rankings and related scores as shown in Table 21.

Estimating the probability of implementation of this plan is a difficult task since the implementation depends on deployment in each of the 147 cities, villages and towns within the Region, or on a somewhat smaller number of cooperative municipal service areas. Counties are excluded since they are better served by the Regional Wireless Plan. Regional communities have already begun to consider the process of deploying community wireless networks, but the probability of all of the communities in the Region adopting community wireless plans within the plan implementation period is judged to be about 60 percent, for a probability estimate of 0.6. Combining the probability with the rank valuation score of 54 produces a total plan evaluation value for the Community-Based Wireless Plan of 32.4.

Regional Wireless Plan

Following the same scoring procedure, the rankings and related scores for the Regional Wireless Plan are shown in Table 22.

Initially, the probability of implementation of a regional wireless plan was judged to be rather low because there is no regional governmental authority to carry out such a plan. Recent experience with a potential demonstration project in Kenosha County, however, indicates a higher probability of implementation on a county-by-county basis. A successful implementation of the plan in a single county such as Kenosha could ignite sufficient interest for other counties to follow suit for an

Table 23

FIBER-TO-THE-NODE (FTTN) WIRELINE PLAN RANKINGS AND RELATED SCORES

Item	Performance	Universal Geographic Coverage	Infrastructure Cost	Redundancy	Public Safety	Most Demanding Application
Rank	2	3	3	3	3	2
Score	3	2	2	2	2	3
Weight	6	5	4	3	2	1
Value	18	10	8	6	4	3

Note: Summation of the above value provides a total valuation score of 49.

Source: SEWRPC.

Table 24

FIBER-TO-THE-PREMISES (FTTP) WIRELINE PLAN RANKINGS AND RELATED SCORES

Item	Performance	Universal Geographic Coverage	Infrastructure Cost	Redundancy	Public Safety	Most Demanding Application
Rank	1	4	4	3	4	1
Score	4	1	1	2	1	4
Weight	6	5	4	3	2	1
Value	24	5	4	6	2	4

Note: Summation of the above value provides a total valuation score of 45.

Source: SEWRPC.

eventual regionwide deployment. Such a possibility raises the probability of implementation to 60 percent (0.6) for a plan evaluation value of 39.0.

The Kenosha County joint public safety/WiFiA wireless communications demonstration project is currently at the contract closure stage and is scheduled to begin in September, 2007. The project activities will include a detailed 4.9 GHz (public safety) and 5.8 GHz (commercial WiFiA) plan followed by a field demonstration of long-range, high-performance at 4.9 GHz communications with law enforcement vehicles. The project will also include a demonstration of peer-to-peer backup communications for public safety that would provide for network continuity when infrastructure is damaged in major public emergencies. If the field demonstration project is successful, Kenosha County intends to implement an early broadband public safety communications safety deployment that is county-wide in coverage.

Fiber-to-the-Node (FTTN) Wireline Plan

The FTTN Wireline plan rankings and related scores are shown in Table 23.

The probability of FTTN plan implementation is quite high since AT&T is already implementing an FTTN network in the Region. The primary obstacle to assigning a probability implementation of 100 percent is that AT&T is not the ILEC in all of the FTTN proposed service areas within the Region. AT&T has also clearly stated that it will not provide universal geographic coverage, but coverage only in those areas promising an adequate economic return. These limitations lower the implementation value to 0.8, the highest of any of the plan alternatives. Such a probability produces an FTTN plan evaluation value of 39.2.

Fiber-to-the-Premises (FTTP) Wireline Plan

The FTTP Wireline Plan rankings and related scores are shown in Table 24.

With the major regional ILEC, AT&T deploying a lower cost alternative wireline technology (FTTN), the probability of implementation of an FTTP network must be considered extremely low. AT&T must recover its return on the FTTN investment, and the FTTN nodal infrastructure still leaves the major costs of an FTTP to be covered in a network expansion. These costs relate to the fiber installation expenses from the nodes to each of the user premises. A probability of implementation of 0.3 seems appropriate. Such a probability produces an FTTP plan evaluation value of 13.5.

Rank-Based Expected Valuation (RBEV) Summary

The RBEV summary of the four alternative plans in priority order is listed below:

1. Regional Wireline Plan – V=39.0

2. FTTN Wireline Plan – V=39.2

3. Community-Based Wireless Plan – V=31.2

4. FTTP Wireline Plan – V=12.6

The above RBEV evaluation produces essentially the same values for the FTTN wireline plan and the Regional Wireless Plan. Each contributes a different set of attributes to regional telecommunications capabilities. The Regional Wireless Plan provides universal geographic coverage throughout the Region and significantly enhances the state of public safety communications in the seven county area. The FTTN plan provides the beginnings of an areawide fiber network in urbanized areas and provides competition in cable television service. A major cost factor not considered in the evaluation is the sharing of the cost of infrastructure deployment between county governments and private providers that would be possible under implementation of the Regional Wireless Plan. Such cost sharing would reverse the above plan rankings and designate the Regional Wireless Plan as the preferred broadband telecommunications plan for the Region. In actual practice, both plans satisfying complementary needs may be expected to proceed toward plan implementation.

None of the above primary plans provide for the mobile (cell phone) users. The fiber link plans, both FTTN and FTTP, do not provide for either the nomadic (laptop computer) or the mobile user. The community and regional wireless networks offer broadband communication services to the nomadic user. Since mobile communications will play a dominant role in future broadband communications, each of the above primary plans must be supplemented with an adjunct broadband mobile wireless network.

WiMAX versus WiFi for a Regional Mobile Broadband Wireless Network

The two alternative broadband wireless networks described in Chapter VII utilized either WiMAX or WiFi technologies. Adjunct Plan A was an independent plan based on WiMAX (IEEE Standard 802.16e) and deployed 743 base stations throughout the Region. Adjunct Plan B was a true adjunct plan in that its implementation depended on the pre-existence of one of the two alternative wireless plans—regional or community-based—for its implementation. Following the same approach used for the primary alternative plan evaluation, these two adjunct plans will be rank-evaluated for each of the Chapter III objective standards.

Performance Objective

Early released versions of WiMAX mobile wireless technology do not provide for the throughput data rates of 20 megabits per second as specified in the Chapter III performance standard. Later versions will probably improve in performance but at an unknown rate. The WiMAX plan illustrated in Map 36 in Chapter VII, depicts 20 megabits per second performance in most areas throughout the Region. Such performance was achieved through the deployment of a very large number of antenna base stations (743).

The WiFi and WiFiA based mobile wireless plan, as illustrated in Maps 37 and 38 in Chapter VII, achieves the specified throughput performance using the community-based wireless network but not with the regional wireless network. Some new features will be added to the regional wireless plan to upgrade throughput performance to standard level, but these features are still untested and so can not be relied upon at this time. Given the uncertainty in this aspect of the regional wireless plan, the WiMAX plan must be ranked higher.

1. WiMAX Mobile Wireless Plan A

2. WiFi Mobile Wireless Plan B

Universal Geographic Coverage Objective

Because it employs licensed radio frequency bands, the WiMAX adjunct mobile wireless plan A must be deployed by a major wireless carrier that owns spectrum in these licensed bands. The high cost of region-wide WiMAX deployment combined with the low economic return expected in lower density rural areas makes it highly unlikely that any private wireless carrier would provide region-wide mobile wireless WiMAX coverage. WiFi Plan B, in contrast, operates off a primary wireless infrastructure, either the regional and the community-based, and so has a reasonably high probability of region-wide implementation. Given this situation, the WiFi mobile wireless plan outranks its alternative adjunct WiMAX plan.

1. WiFi Mobile Wireless Plan B
2. WiMAX Mobile Wireless Plan A

Infrastructure Cost Objective
With an estimated infrastructure cost of $38.0 million, the mobile wireless WIMAX plan far exceeds in cost any added features needed to extend the range or performance of the Regional Wireless Plan for mobile users as called for in Adjunct Mobile Wireless Plan B. With the Community Based Wireless Plan, there is little or no added infrastructure costs to support mobile wireless users. The Regional Wireless Plan will require some infrastructure augmentation, but at no where near the level of the WiMAX alternative. In either event, the WiFi adjunct plan provides a lower cost alternative than WiMAX based Plan A.

1. WiFi Mobile Wireless Plan B
2. WiMAX Mobile Wireless Plan A

Redundancy Objective
Both the regional and community-based primary wireless plans will be augmented by design features that allow for alternate transmission paths through the network. Based on such design features, WiFi adjunct plan B will have built-in redundancy not known to be featured in WiMAX. For this reason, the WiFi-based mobile wireless plan must be ranked above the WiMAX alternative for network redundancy.

1. WiFi Mobile Wireless Plan B
2. WiMAX Mobile Wireless Plan A

Public Safety Objective
A major feature of the Regional Wireless Plan is its joint public safety-commercial capabilities. As an adjunct to the Regional Wireless Plan, the WiFi Mobile Wireless Plan B would incorporate a capability for communication with hand-held devices, including cell phones. WiMAX mobile wireless networks could also operate in the 4.9 GHz public safety frequency band, but this additional capability is not likely to be incorporated in a region-wide WiMAX network by a private wireless service provider. As an adjunct to a community-based WiFi network, Plan B also requires a 4.9 GHz upgrade. On balance, however, the WiFi mobile wireless Plan B better serves this objective.

1. WiFi Mobile Wireless Plan B
2. WiMAX Mobile Wireless plan A

Most Demanding Application Objective
With equivalent bandwidth capability, both the WiFi and the WiMAX can serve the demands of video and multimedia communications. The improved quality of service (QoS) features of WiMAX would appear to favor WiMAX for this objective.

1. WiMAX Mobile Wireless Plan A
2. WiFi Mobile Wireless Plan B

RANK-BASED EXPECTED VALUE ADJUNCT PLAN EVALUATION

Based on the above rankings, Tables 25 and 26 summarize the valuation scores for the WiMAX and WiFi mobile wireless plans.

WiMAX Mobile Wireless Plan A
The probability of implementation of a broadband mobile wireless plan must be considered rather low because of the cost and the low financial return in rural areas of the Region. There is also some basis for questioning the need for 4G-level throughput in many areas of the Region. These uncertainties result in a implementation probability of only 0.3 which results in a plan evaluation value of only 8.4.

WiFi Mobile Wireless Plan B
The probability of implementation of this WiFi mobile wireless plan is quite high since it operates off the infrastructure of either the regional or community-based wireless plan. Given the region-wide deployment of either of these fixed user plans, the addition of a mobile wireless capability is judged to be highly likely, so that it should be assigned the same probability of implementation as those two plans which is 60 percent or 0.6. Such a probability value results in a total plan evaluation value of 21.0.

Table 25

WiMAX MOBILE WIRELESS PLAN A RANKINGS AND RELATED SCORES

Item	Performance	Universal Geographic Coverage	Infrastructure Cost	Redundancy	Public Safety	Most Demanding Application
Rank	1	2	2	2	2	1
Score	2	1	1	1	1	2
Weight	6	5	4	3	2	1
Value	12	5	4	3	2	2

Note: Summation of the above value provides a total valuation score of 28.

Source: SEWRPC.

Table 26

WiFi MOBILE WIRELESS PLAN B RANKINGS AND RELATED SCORES

Item	Performance	Universal Geographic Coverage	Infrastructure Cost	Redundancy	Public Safety	Most Demanding Application
Rank	2	1	1	1	1	2
Score	1	2	2	2	2	1
Weight	6	5	4	3	2	1
Value	6	10	8	6	4	1

Note: Summation of the above value provides a total valuation score of 35.

Source: SEWRPC.

It is clear from the above that the WiFi mobile wireless plan is the best plan as indicated by the ranked based expected value score and probably the only broadband wireless plan able to economically achieve 4G standards in the entire Region.

Regional Comprehensive Broadband Telecommunications Plan Selection

Based on the Rank-Based Expected Value scoring, the leading contender for adoption as the regional telecommunications plan would be the Regional Wireless Plan supplemented by the WiFi Mobile Wireless Adjunct Plan. Together, these two complementary plans would meet the objectives and standards established in Chapter III for a comprehensive, regional broadband telecommunications system to serve the Region in the coming decade. Other considerations, however, require the provision of flexibility in the structure of the plan. This flexibility is required for the following reasons:

1. Existing and Expected Broadband Wireline Network Deployments – AT&T has already begun the deployment of a Fiber-to-the-Node Broadband Wireline Network in Southeastern Wisconsin. Time Warner and Charter Communications also have the potential of upgrading their cable network in a modified FTTN configuration to satisfy fourth generation broadband requirements. Since these new or modified networks are at least in partial compliance with current 4G objectives and standards, flexibility must be provided within the recommended plan to accommodate the continued deployment of these wireline networks.

2. Existing and Expected Community-Based Broadband Wireless Network Deployments – Strong interest in community-based broadband wireless networks currently is evident within the Region. Initial deployment of some of these networks is already underway. Since those networks would operate in a different frequency band than that which would be

used for the regional wireless plan—2.4 GHz for the Community-based systems and 5.8 GHz for the regional plan—they are operationally compatible and could serve together in the Region.

3. Broadband Communications Competition – In the current regulatory environment, consumer protection and technology innovation are both fostered by competition. It is Federal communications policy as set forth by the Congress and the Federal Communications Commission to encourage such competition. For these reasons, the recommended regional broadband telecommunications plans must provide for a level of diversity that recognizes current trends and the desire for a competitive telecommunications environment.

With the Rank-based Expected Value evaluation results as a foundation, but upon consideration of the foregoing trends and the desire for broadband competition in the Region, the following composite regional comprehensive broadband telecommunications plan is recommended for adoption within Southeastern Wisconsin:

1. Regional Wireless Plan for region-wide broadband coverage to serve fixed and later nomadic users; and

2. WiFi-based Mobile Wireless Plan B for region-wide broadband coverage of mobile users.

The above primary plan components would be supplemented by:

1. Fiber-to-the Node Wireline Plan

   - to provide television and related broadband services within the urbanized areas of the Region.

2. Community-Based Wireless Plans

   - for communities selecting local networks to compete with and complement the regional wireless networks.

   - to further support the WiFi-based Mobile Wireless Plan B.

Public Sector Broadband Wireless Networks

All of the above alternative broadband communications plans relate to commercial networks generally owned and operated by private service providers. These plans and the final selected composite plan are intended as an advisory plan to the private sector. A separate class of telecommunications networks relate to functions performed by the public sector. These public enterprise telecommunications networks were described in SEWRPC Memorandum Report No. 164, *Potential Public Enterprise Telecommunications Networks for Southeastern Wisconsin*, September, 2005.

One of the particularly important classes of potential public enterprise telecommunications networks described in the aforereferenced report are public safety emergency response networks which support law enforcement, firefighting, pre-hospital emergency medical service (EMS), and public works personnel with their communications needs. This class of network was described in the aforereferenced report with emphasis on high speed data, video, and multimedia applications in the new FCC (2002) frequency spectrum of the 4.9 GHz band. This band is dedicated solely to public safety applications and has sufficient bandwidth—50 MHz—to support high speed fourth generation (4G) communications performance. Experimental deployment of 4.9 GHz is expected in the next few years. Initial applications will emphasize data and video transfer, but extension to voice communication is expected to rapidly follow.

There is a strong synergy between the needs of public safety communications and the recommended regional telecommunications plan. Based upon interoperability needs, there is broad agreement that public safety communications should be regional in nature. The perpetuation of various community-based communications networks is not in the interest of effective operations particularly in times of major, disaster-level emergencies.

The wireless element of the recommended regional telecommunications plan could not only support commercial broadband wireless communications, but also region-wide, interoperable public safety broadband telecommunications. The estimated infrastructure cost of the recommended plan of $6.4 million made no allowance for base station site cost sharing between the public and commercial wireless networks. The close proximity of the public safety band—4.9 GHz—and the commercial WiFiA band—5.8 GHz—makes such base station cost sharing feasible and useful. Such cost sharing would further reduce the regional wireless plan infrastructure cost, and would allow for ready accomplishment of region-wide geographic coverage, an important objective of the regional telecommunications planning effort. Thus the recommended regional telecommunications plan has a unique advantage in being able to support both commercial and public sector broadband telecommunications in the Region.

Chapter IX

PLAN IMPLEMENTATION

The recommended regional telecommunications plan described in Chapter VIII of this report provides a design for the attainment of the specific regional telecommunications objectives set forth in Chapter III of this report. In a practical sense, this recommended plan is not complete until the actions required to implement it, that is to convert the plan into action policies and programs that result in actual network deployments, are specified. This Chapter is, therefore, presented as a guide for use in the implementation of the recommended plan. This Chapter sets forth a recommended procedure for plan implementation, outlining the actions which must be taken by the various public and private agencies concerned if the recommended plan is to be fully carried out. Those public and private agencies which have plan adoption and plan implementation functions applicable to implementation of the recommended plan are identified; the necessary formal plan adoption or endorsement actions are specified; and specific implementation actions are recommended for each of the public and private agencies concerned.

Plan implementation as presented here extends beyond the physical and technical development of the telecommunication networks to the business and operational models required to effectively fund, market and operate the networks concerned. The business model addresses the economics of a telecommunication system in terms of the user charge rates required for economically viable operation, as well as the marketing activities needed to establish and operate the facilities and services envisioned in the plan. The operational model is concerned with network management and an associated network monitoring system necessary to supervise network operation. The plan implementation recommendations are based upon and related to the existing public and private agency programs functioning within the Region. Given the predominance of the private sector in telecommunication network development, a well-defined procedure for plan implementation becomes an important element of the plan itself.

The currently prevailing telecommunication systems development process within the United States, as established by Federal law, places the responsibility for system development generally within the private sector, that process being, however, regulated by Federal and State laws and regulations. Public Telecommunications service planning efforts such as that conducted by the Southeastern Wisconsin Regional Planning Commission are intended not to replace, but rather to supplement this competitive, market oriented process in the public interest. The adopted regional plan and its recommended implementation efforts are not intended in any way to impede the implementation of alternative plans prepared and put forth by private providers, or by communities or municipalities within the Region, that would move the existing level of service toward the attainment agreed upon objectives and standards. It is, however, hoped that the adopted plan would serve as a point of departure for further telecommunication planning by private providers and public agencies.

Because of the complex combination of public and private interests involved in the provision of telecommunication facilities and services within the Region, and because of the ever present possibility of unforeseen changes in economic conditions, in State and Federal legislation, in case law decisions, in governmental organization, and in public and private fiscal policies, it is not possible to declare, once and for all time, exactly how a process as complex as regional telecommunication plan implementation should be pursued. In the continuing planning process it will, therefore, be necessary to not only update periodically the recommended plan, and the data and forecasts on which the plan is based, but also the recommendations for implementation.

PLAN ADOPTION OR ENDORSEMENT

Public plan implementation measure must grow out of adopted plans. Because of the completely advisory role of the Commission, implementation of the recommended regional telecommunications plan will be entirely dependent upon action by the county and municipal units of government which constitute the Region, and by the private telecommunication facilities and service providers operating within the Region. If plan implementation is to proceed in an effective, coordinated way, adoption or endorsement of the plan by various potential implementing agencies is highly desirable.

Commission Plan Adoption and Certification

The Regional Planning Commission is empowered by State law to prepare and adopt a master plan for the physical development of the Region. It has no statutory plan implementation powers. Its powers are limited to, among others, publicizing plans; issuing reports; and providing—on request—planning assistance to county, municipal and special purpose units of government within the Region. For the recommended regional telecommunication plan to have official status, it must be adopted by the Regional Planning Commission itself, and such adoption constitutes the first action to be taken toward plan implementation. In accordance with the *Wisconsin Statutes*, the Commission—following such adoption—transmits certified copies of the resolution adopting the plan and the plan itself to the legislative bodies of the counties, local municipalities and special purpose units and agencies of government concerned. Such transmittal may also be made to concerned Federal and State agencies, including, in this case, the Wisconsin Public Service Commission.

County and Municipal Plan Endorsement

Endorsement, or formal acknowledgement of the transmitted resolution and plan by the county and municipal units and agencies of government, and by the State agencies concerned is desirable, and may in some cases be necessary, to assure a common understanding between the several levels of government concerned and to enable their staffs to program necessary implementation work. The plan endorsement actions should extend to special purpose agencies such as the Regional Telecommunications Commission, a cooperative agency serving a number of local municipalities within the greater Milwaukee area. It is important in this respect to understand that endorsement of the recommended telecommunications plan by any unit or agencies of government pertains only to the statutory statutes and functions of the adopting agency, and such endorsement itself cannot in any way preempt action by another unit or agency of government within its jurisdiction.

Private Service Provider Endorsement

Private wireless or wireline service providers do not typically have an explicit endorsement process for Commission-developed infrastructure plans. Instead, they may implicitly endorse the plan by their organizational decisions that deploy telecommunications networks consistent with the approved regional plan. Wireline service providers such as AT&T will deploy broadband networks such as their new FTTN network only in so far as they are consistent with independently developed corporate plans.

The role of private service providers in the newly planned wireless networks is significantly different. In the regional wireless plan, the county is the key governmental agency. Endorsement of the plan by a county will set the stage for plan implementation involving private service providers as described in the section below. Adoption of a community-based wireless plan by a local unit of government will, in a similar manner, open the way for private service providers to participate in plan implementation.